A.D. 1866, 18th January. N° 165.

Electric Telegraph Apparatus.

(*This Invention received Provisional Protection only.*)

PROVISIONAL SPECIFICATION left by Cornelius Varley and Samuel Alfred Varley at the Office of the Commissioners of Patents, with their Petition, on the 18th January 1866.

We, Cornelius Varley, of 337, Kentish Town Road, in the County of Middlesex, and Samuel Alfred Varley, of 66, Roman Road, Holloway, in the said County of Middlesex, Telegraph Engineers and Contractors, do hereby declare the nature of the said Invention for "Improvements in Electric Telegraph Apparatus, Parts of the Invention being applicable to other Purposes," to be as follows:—

Our Invention consists in an improved method of constructing single and double needle instruments, and other telegraph apparatus, these improvements having for their object greater durability on the part of the instruments, and less liability to derangement either from mechanical causes, or from being struck by lightning, and greater sensitiveness to feeble electric currents.

We make the outer cases of our needle and other analogous telegraph instruments which heretofore have been made of wood of cast iron, and the bush or bearing in which the axle works in one piece with the case. The axle is made of gun metal or any other suitable metal, and is constructed with a square on one end for the instrument handle to fit on to, and with a transverse piece at the other end which is usually made in a line with the handle. Two holes are bored in the upper end of the transverse piece at the sides, and two insulating pins are fitted into these holes; these pins project a little way on both sides. What is technically known as the bridge of the needle instrument is fixed a little above the top of the transverse piece. Two upright springs, which we call Nos. 1 and 2, press against the bridge on either side;

these are attached at the lower end to blocks of metal, and in some cases to blocks of wood. When the handle of the instrument is moved over to the right-hand side spring, No. 1 is removed from contact with the bridge by means of one of the insulated pins. When the handle is moved to the left-hand side spring, No. 2 is removed from the bridge by the insulated pin fitted into the other side of the transverse piece. When the handle is vertical, both Nos. 1 and 2 springs press against the bridge. We prefer in most cases instead of letting the lower end of the transverse piece come in direct contact with the metal blocks, as before described, to extend the metal blocks downward some distance (4 inches will be sufficient) and attach springs, which we call Nos. 5 and 6, to the sides of the blocks for the transverse piece to beat against the upper parts of Nos. 5 and 6. Springs come into contact with the transverse piece when the instrument handle is moved; the lower ends of these springs are attached to the bottom of the blocks. A recess is cut into the sides of the blocks to allow Nos. 5 and 6 springs to be pushed in a definite amount, their motion in the other direction is also limited by so fixing Nos. 1 and 2 springs to their respective blocks that their lower ends lap a little way over the upper ends of Nos. 5 and 6 springs. The bridge and Nos. 1, 2, 3, 4, 5, and 6 springs and blocks attached to them are insulated from the iron case. The plan we prefer for doing this is to take a piece of well seasoned wood which has been soaked for a time in melting paraffine or hot linseed oil, and cut a hole through it to allow the axle bush which projects a little distance in the inside of the case to pass through. We fit the blocks carrying the springs and the bridge on to this slab of wood; we then take another piece of wood, of a similar size but much thinner, and place it behind the board on which the work has been fitted; both pieces are then placed into the cast-iron case, and bolted to it. Ebonite may be employed in place of wood for insulating the different parts.

The different portions of the instrument are connected as follows:—No. 1 spring is connected to a terminal or binding screw, which we call B; No. 2 spring is connected to one end of a galvanometer coil; the other end of the galvanometer coil is connected to a terminal called A; Nos. 3 and 4 springs are connected to a terminal called Z; the axle is connected to a terminal called C All these terminals, with the exception of C, are insulated from the iron case. The instrument is connected up as follows:—If the instrument be fixed at a terminal station, terminal B is connected with the line, and terminal A to the earth, or vice versâ. If the instrument be placed at an intermediate station A is connected to the line wire on one side of the station, and B to the line wire on the other side of the station. Terminal C is connected with the copper pole of a galvanic battery, and Z with the zinc pole of the battery.

When a current is being received it passes from the line wire to terminal B through the galvanometer (deflecting the needle) to No. 2 spring across the bridge to terminal A, and thence to the earth. When sending a current if the handle be moved to the right, No. 1 spring is pressed away from the bridge and against spring No. 3, which is connected to the zinc pole of the battery, the lower end of the transverse piece, which is connected through the metal case to the copper pole of the battery is brought into contact with the block of metal attached to No. 2 spring, and a positive current is sent through the galvanometer on to the line wire connected to terminal B. When the handle is moved to the left the zinc pole is brought into contact with No. 2 spring, and the copper pole with No. 1 spring, and consequently a negative current passes along the line.

We construct our galvanometers as follows:—We wrap the coils on frames or bobbins with moveable cheeks, so that after the coils are wrapped the bobbins on which the wire has been wrapped can be removed. These bobbins are made in the shape of segments of a circle. After the coils have been wrapped they are immersed for a time in a bath of any suitable melting cement; they are then removed from the bath and the bobbins carefully taken to pieces, the wires retaining their position by the adhesion of the cement. The coils are then placed in a mould of the shape the coils are intended to be when finished and compressed. This brings the convolutions closer together and forms them into axact segments of a circle. When the cement has hardened by being cooled the coils are removed from the mould and placed in a circular chamber or box. The coils being segments of a circle pack closely together. The coils are of such a length that they do not reach to the centre of the circular box, but leave a central space. In this space and at right angles to the circular box the pole of a powerful permanent magnet is inserted. A circular soft iron disc, with soft iron bars radiating from it, is mounted on an axle over the pole of the permanent magnet. The radiating bars are made of even numbers so that they may be opposite one another and pass over the surface of the segmental coils. The axle terminates in a fine pivot which works in a pivot hole made in the pole of the permanent magnet. The soft iron disc and its radiating bars become magnetic by induction from the permanent magnet underneath, and all the bars being magnetized in a similar way they are practically astatic. To prevent the friction in the pivot hole, which would be caused by the inducing magnet pulling the iron disc towards it, a second iron disc with radiating bars exactly similar to that before described is mounted on the same axle higher up. This second disc is so mounted on the axle that if a perpendicular line be dropped from the upper

radiating bars when the axle is vertical it will pass exactly between the bars radiating from the lower disc. Over the upper disc another permanent magnet is mounted which magnetizes it, and the bars radiating from it by induction, and there is also an arrangement by means of which the pole of the upper permanent magnet can be adjusted nearer or farther from the upper disc, by raising or lowering this adjustment the attractive forces of the upper and lower permanent magnets on the soft iron discs can be balanced. The number of radiating bars in each disc is half that of the coils, that is to say, if there be 12 segmental coils, each occupying a space of 30 degrees, there will be 6 radiating bars in each disc 60 degrees apart from one another on their respective discs. The lower soft iron disc is generally mounted below the surface of the coils, and the radiating bars are first bent at right angles or nearly so to the disc, and then bent again so as to move in a plane over the surface of the coils. The radiating bars of the upper disc are also bent so that they move in the same plane over the surface of the coils as the radiating bars of the lower disc, and being exactly between them the distance between the radiating bars of the upper and lower discs is 30 degrees, and consequently there is a radiating bar over each coil. The inducing pole of the upper permanent magnet is of the opposite polarity to that of the lower permanent magnet, the radiating bars are therefore magnetized alternately north and south. The segmental coils are also so joined up that when an electric current is sent through them the centres of the coils become alternately south and north. A second series of segmental coils can be arranged over the upper surface of the radiating bars to increase the force of the electric current. When an electric current is sent through the coils the radiating bars arrange themselves over the centres of the coils according to the direction of the electric current, and being highly magnetic, and at the same time not influenced by the earth's magnetism, the instrument is very sensitive. The sensitiveness of the instrument can be still farther increased by fixing a mirror on the axle carrying the discs and reflecting a beam of light on a screen.

In some cases we make the radiating bars of magnetized tempered steel, and do away with the inducing magnets; but where great sensitiveness is required we prefer using soft iron radiating bars and inducing magnets; and when we desire the greatest possible sensitiveness we replace the permanent inducing magnets by electro-magnets.

This galvonometer form a very good relay for working Morse printing instruments or for relay transmission. When we use it for this purpose we mount a light metallic arm on the axle carrying the soft iron discs, having a

piece of platina or platina alloy fixed to it where it touches the contact points. This relay works between two contacts in a similar way to what are known by the name of polarized relays, but instead of using fixed points for the relay arm to beat against we mount small wheels or rollers made of gold or platina alloy. Motion is communicated to these wheels by two hard rollers made of bell metal or other hard non-magnetic metal rolling against them. These bell-metal rollers are driven by means of a simple piece of clockwork, which we prefer being made entirely of brass or other non-magnetic metal. The gold rollers revolve in the same plane as the relay lever, and when the contact lever beats against them any film of air adhering to the roller is wiped away and better contact made; the lever is also less liable to stick than in other relays when working with very weak currents. The object of communicating the motion by another roller is that it burnishes down the roughness caused by the electric current melting the metal at the point of contact.

When the galvanometer is intended for currents of large dynamic quantity the segmental coils and the soft iron radiating bars may be so arranged that the bars radiating from the lower disc pass under the under surface of the coils, and the radiating bars of the upper disc pass over the upper surface of the coils, only one set of coils will then be required; but if there be 12 coils, there must be 12 radiating bars in each disc.

When this galvanometer is applied to needle instruments, for the sake of simplicity in construction, we generally employ only two radiating bars and one inducing magnet, and instead of putting the inducing magnet at right angles to the box we place it in the same plane as the surface of the coils, and cut 2 slots in the pole of the inducing magnet at right angles to each other; the axle carrying the soft iron disc passes between one of these slots, and the disc and radiating bars between the other.

We also employ the following modification for needle instruments:—We take a piece of brass tube, say, 5 inches in diameter and about $1\frac{1}{2}$ inches deep, and fit into the 2 ends two flat brass discs with a hole through their centres. These flat discs form the top and bottom of the box, and are generally sprung in so that they can be removed. We then wrap 4 circular coils 2 inches in diameter and about $\frac{1}{2}$ inch thick. Two of these coils are mounted on the bottom of the box close to its circumference, and are so placed that a line drawn from the centre of one coil to the centre of the other passes across the centre of the disc forming the bottom of the box. The two other coils are fitted on the inside of the top of the box, and when the top is put in its place lay exactly over the two coils attached to the bottom of the box leaving a space between them. A segment of a hoop of soft iron,

the internal diameter of which is about 1 inch $\frac{5}{16}$ths, and whose outer diameter is about 1 inch $\frac{11}{16}$ths is attached to the bottom of the circular box. This segment is placed in the box, so that all parts of its inner side are at an equal distance from the centre of the disc forming the bottom of the box, and is of the same thickness as the coils. These segments occupy a space of 90 degrees each, more or less. Another similar segment is attached to the inside of the top of the box on the opposite side to the other segment. In the space left between the coils and at right angles to a line drawn through the two centres of the coils a soft iron bar is fixed, one end of this fits closely against the piece of circular iron attached to the bottom of the box, the other end of the bar projects some distance out of the side of the box; a hole is drilled through this bar where it crosses the centre of the box. A similar but shorter piece of iron is attached to the inside of the top of the box, this bar projects the same distance outside as the one before described, and the inner end fits closely to the outer side of the piece of circular iron attached to the inner side of the top of the box. A light hoop of soft iron, the outer diameter of which is about 1 inch $\frac{5}{8}$ths, and the inner diameter about 1 inch $\frac{3}{8}$ths is mounted in any suitable way on an axle which passes right through the box terminating in pivots, which run in pivot holes drilled in cocks attached to the outside of the top and bottom of the box. A portion of this iron hoop is cut away in two places, leaving 2 pieces of a circle with a space dividing the extremities of each, one of these pieces passes over the quarter circle of soft iron attached to the inside of the bottom of the box; the other piece moves over the quarter circle attached to the inside of the top of the box. The north pole of a horse-shoe magnet is attached to one of the bars of soft iron projecting out of the side of the box, and the south pole to the other. These magnetize by induction the two pieces of circular iron mounted on the axle, one of the pieces being magnetized with south polar magnetism, and the other with north polar magnetism; when a current is sent through the coils the south pole is attracted to the centre of the coil, and the north repelled to the outside, or vice versa, according to the direction of the electric current passing through the coils.

We prefer in many cases to employ ribbon coils in place of ordinary silk covered wire, and as there is some difficulty in getting copper drawn down to a very thin ribbon, we obtain our conductor in the following way:—We obtain a long length of very thin paper of the suitable width, and pass it through melting paraffine or other suitable insulating material. We then coat one side of it with blacklead or fine metallic powder to make a conducting surface; the paper ribbon is then passed through a depositing trough and a thin coating of copper electrotyped upon it. In this way we obtain a

very thin metallic conductor. After removal from the bath the paper ribbon is washed and dried and passed through the bath of melting paraffine again, and it is now ready for use.

To protect the coils from being damaged by lightning striking the wires we take advantage of the property of powdered conducting matter when in a fine state of division to offer great resistance to the passage of an electric current of moderate tension, whilst it offers comparatively but little resistance to currents of high tension. We connect the terminal of the telegraph instrument which is connected with the line wire to a stout piece of copper which passes into a chamber of insulating material and terminates in a point; another piece of copper is fixed in the same chamber in close proximity to the copper point, but not actually touching it. We now place finely divided powder in the chamber in sufficient quantity to cover the two pieces of copper. This second piece of copper may be either connected to the earth or to the other extremity if the insulated wire of the galvanometer coils. When lightning strikes the wires instead of passing through the convolutions of insulated wire forming the coils, it will pass across the space separating the two pieces of copper, and the passage across will be further facilitated by the powder enveloping the pieces of copper. A very suitable powder is charcoal in a fine state of division, but any powder will assist the passage of high tension electricity.

In some cases when we employ charcoal powder we make it red hot to drive out anything it may have absorbed, and seal the chamber up after putting it in; the absorptive power of the charcoal forms a partial vacuum, which further facilitates the passage of an electric current.

We adopt the following plan when we want to obtain the most perfect protection:—We take cylinders of glass or other suitable insulating material having a hole through the centre; we grind the two ends of the hole slightly conical and of a true figure. We then turn two cylinders of metal with points at their extremities to go easily into the hole through the glass cylinders. These pointed cylinders are placed in at the ends, so that the points meet at the centre of the hole in the cylindrical piece of glass; they are prevented from actually touching by shoulders cast upon the metal cylinders, which are turned conical to fit the conical ends of the hole in the cylindrical pieces of glass. To insure more perfect fitting these shoulders are coated with lead or other soft metal, and pressed closely against the ends of the cylindrical piece of glass by being placed between two discs and forced together by suitable bolts passing through the discs; the discs are insulated from one another. Through one of these metal cylinders there is a small hole communicating with

the interior of the glass cylinder, previously to bolting the parts together sufficient finely powdered charcoal is placed in the interior of the glass cylinder to cover the two metal points. They are then bolted together, and the air pumped out of the interior of the cylinder of glass by means of an air pump, and the small hole in the metal cylinder soldered or sealed up while it is connected with the air pump to prevent the re-admission of the air.

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